

## Technology Mirror Assembly Testing

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The realignment of the technology mirror assembly (TMA) is completed, and x-ray detector assembly calibration rehearsal with the TMA at the X-Ray Calibration Facility (XRCF) at MSFC is underway. During the calibration rehearsal, several x-ray detector assemblies will be checked out with the TMA. The TMA alignment requirements are 0.75-arc sec relative tilt or 44- $\mu$ m spot diameter.

The TMA was built in the mid-1980's as a part of the AXAF development program in order to gain valuable experience with grazing incidence mirror fabrication, metrology, and alignment techniques. Much of the experience was applied in fabrication and testing of the AXAF's high-resolution mirror assembly (HRMA).

The TMA's diameter is 410 mm, or approximately one-third of the HRMA's outer diameter, and half of HRMA's length. Its focal length is 6 m. TMA consists of a parabola and hyperbola mirror supported by graphite-epoxy cylinders which are supported by aluminum center aperture plates. Each of the mirrors is bonded to four invar pads. The pads are bonded to the graphite-epoxy mirror support.

The TMA was aligned and tested in the late 1980's at the XRCF. The alignment of the TMA was found to be unstable during the x-ray testing. Tested with a sensitive acoustic instrument, one of the graphite-epoxy pads indicated a difference in response and was suspected to be debonded or partially debonded from the TMA's parabola mirror. The TMA had been in storage since 1990. Classified as program critical hardware, it was taken out of storage in 1995.

Alignment of the TMA requires a specially

built alignment instrument. This instrument consists of a Helium-Neon laser source, a rotating scanner, and a detector. The laser output, a beam from the TMA's focus to the exiting aperture, retroreflects off an 18-in-diameter precision flat mirror and double passes through the TMA and back onto the detector to analyze the relative misalignment of the TMA. Earlier alignment attempts determined that the alignment could be improved by applying external forces to the ends of the TMA.

In the first realignment attempt, the TMA was found to be misaligned and it required 56 lbf to align the hyperboloid to the paraboloid mirror. The alignment in 1989 required only 24 lb of lateral force to align the TMA. With the 56 lb of stainless steel weights, the TMA was aligned to 0.05 arc sec or 3- $\mu$ m-diameter spot.

Since the TMA was not stored in a clean room, the TMA was subjected to a series of vacuum bakeout at elevated temperature of 110 °F until it passed the MSFC-SPEC-1238. Vacuum bakeout of the TMA was conducted to ensure that it would not contaminate the XRCF during testing. The TMA was brought to the XRCF for final alignment. There the TMA was found to be grossly misaligned (3 arc sec) with more than 100 lbf required to realign the TMA. In addition, another residual error term was much greater than before the vacuum bakeout. The residual error indicated comes from the same quadrant where the debonded pad is located. The cause of this additional error is not known with certainty, but it is known that graphite-epoxy is hygroscopic and changes shape when moisture escapes under vacuum bakeout. A spring-loaded device was fabricated and placed inside the TMA to pull on the paraboloid mirror to correct the residual error. Afterward, it required 80 lb of weight placed on each mirror to align the TMA. The residual error due to relative tilt was between 0.38 arc sec or 21  $\mu$ m. The residual error due to the ovalized parabola mirror (delta-delta radius error) is 36  $\mu$ m. The RSS spot size is 42- $\mu$ m diameter. During the calibration rehearsal,

the x-ray spot diameter is well within specification and seems to be stable and repeatable.

The aligned TMA will be a valuable asset to the x-ray science community. The TMA will serve as an x-ray optical instrument for calibration of any future x-ray detectors in vacuum. The TMA, along with the XRCF at MSFC, will be available to serve the science community in x-ray instrument testings. The lessons learned from the TMA alignment will be valuable in future optical telescope engineering programs.

The TMA with a debonded pad is temporary cured with an internal fixture. Additional forces are needed to realign the TMA. Preliminary test data agrees with the data from the TMA alignment scanner.

**Sponsor:** AXAF Development Program

**Biographical sketch:** Ron Eng is an optical design engineer at the Optics Branch at MSFC. His accomplishments include the wide field angle lenses for the Lightning Imaging Sensor (LIS), Optical Transient Detector (OTD), and the Solar Vector Magnetograph. He received a B.S. degree in optics from the University of Rochester, and took additional graduate courses at the University of Rochester and the University of Alabama in Huntsville. ☼